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Construction-Mineral Aggregate Availability in the Baltimore, Md., Metropolitan Area

UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. Bureau of Mines.

Information Circular 8697

Construction-Mineral Aggregate Availabilty in the Baltimore, Md., Metropolitan Area

By John R. Bitler
Eastern Field Operation Center, Pittsburgh, Pa.

March 3, 1849

UNITED STATES DEPARTMENT OF THE INTERIOR
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CONSTRUCTION-MINERAL AGGREGATE AVAILABILITY IN THE BALTIMORE, MD., METROPOLITAN AREA

by

John R. Bitler[1]

ABSTRACT

The Bureau of Mines conducted this study to provide information concerning the availability of and the demand for construction-mineral aggregates in the Baltimore, Md., Standard Metropolitan Statistical Area (SMSA). The demand is discussed with reference to the area's current consumption and estimates of the area's demand for aggregates through 1990. Estimates of aggregate supply are presented in conjunction with an examination of the geology of the area, the availability of substitutes, and the effect of transportation costs. A discussion of the constraints affecting aggregate availability precedes the conclusions and recommendations.

The availability of aggregates is subject to geologic, economic, and political constraints. As of January 1974, an estimated 20,100 million tons of stone was available to meet the demand projected through 1990 (188.7 million tons). An estimated 139 million tons of sand and gravel was available to meet the demand projected through 1990 (84.3 million tons). Several alternative actions are available within the area to insure the adequacy of the stone supply and to increase the supply of sand and gravel: (1) The establishment of special mineral resource zones; (2) the application of sequential land use techniques; and (3) the exploration of previously undeveloped regions.

INTRODUCTION

Recent urban development in the Baltimore SMSA has given rise to many of the typical land use problems affecting construction mineral aggregate availability. The Baltimore SMSA consists of five counties--Anne Arundel, Baltimore, Carroll, Harford, and Howard--and Baltimore City, as shown in figure 1.

Aggregates--predominately sand and gravel, crushed stone, and crushed blast furnace slag--are used extensively in highway and building construction as base material and fill, and to provide bulk and strength in most types of concrete. Because these low-value materials are produced in large quantities, mining operations are generally near large cities, which are the primary consuming areas, in order to minimize the transportation costs.

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[1] Physical scientist.

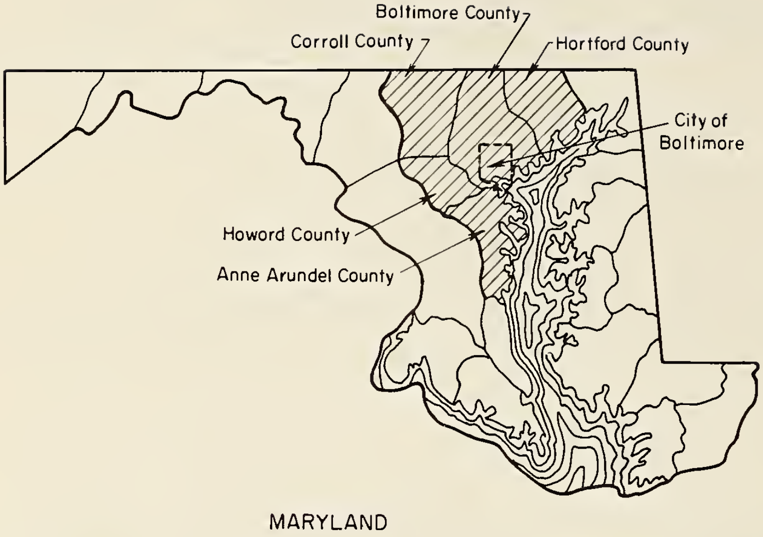


FIGURE 1. - Geographic units comprising the Baltimore region.

In 1973, the aggregate industry, the largest of the mineral industries operating in the Baltimore SMSA, produced 12,400,000 tons of aggregates worth $38,600,000. The 23 firms producing aggregates in the area vary markedly in size: The smallest are sand and gravel pits producing unprocessed material on an intermittent basis; the largest are vertically integrated from aggregate production to construction and land development, with several large-scale operations producing all types of aggregate material. The operations in the area, their locations, and type of product are listed in appendix B, table B-1.

Sand and gravel is usually produced by surface mining methods without employing blasting because of the unconsolidated nature of the deposits. Processing sand and gravel involves sizing and washing to remove such impurities as clay and shale. Crushed stone is produced by surface (quarries) or by underground mining methods involving blasting, followed by crushing and sizing to obtain a usable product. Crushed blast furnace slag, a byproduct of the steelmaking process, is produced in two forms: (1) Air-cooled slag, which is dumped on a slag pile and allowed to cool, and (2) foamed or expanded slag, which is sprayed with water while being dumped into a slag pit to cool. After cooling, the slag is crushed and sized to yield a usable product. The slag consumed in the area originates at Bethlehem Steel Corp.'s Sparrows Point plant.

The aggregate industry has an impact on the area's economy through its position as an employer and taxpayer, and through its relationship to the construction industry of the area. In 1972, the aggregate industry employed more than 800 persons directly involved in mining aggregates. An estimated payroll of $6,600,000 represented approximately 0.2 percent of the total economic activity in the area (27).[2] The most significant aspect of the aggregate industry is the effect of the availability of aggregates on the construction industry. Aggregates are the primary raw materials for the construction industry. Thus, the availability of aggregates will affect the level of construction activity, which in turn has an effect on construction employment and earnings. In 1973 the average annual employment in contract construction was 46,200, approximately 5 percent of the area's total work force (7). The construction industry contributed more than 6 percent of total manufacturing earnings and accounted for 9 percent of the area's economic activity during 1972 (25).

---

[2] Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

The rapid, and at times unplanned, central and suburban development of the area restricts the growth and occasionally prevents the operation of aggregate quarries and pits. Urban and regional planners guide and regulate urban development by restricting land use. These planners often must make decisions affecting the aggregate industry without adequate information regarding the community's needs for the industry's products. This information represents a much needed input to the planning process.

CONSUMPTION

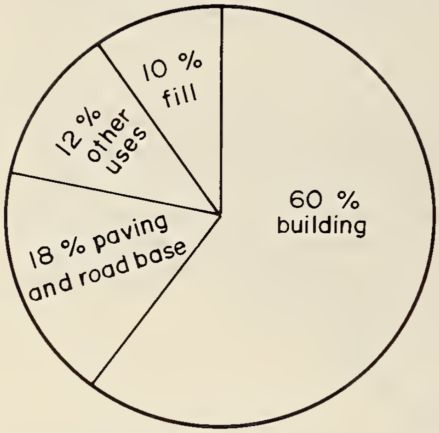
The demand for aggregates--derived from the demand for new, replacement, and maintenance construction--breaks down into three main types of construction: highway, 52 percent; nonresidential, 31 percent; and residential, 17 percent.

In the Baltimore SMSA, aggregate consumption exceeds production; imports from other areas comprise the difference. During 1973, approximately 1.5 million tons of sand and gravel and crushed stone were shipped into the Baltimore SMSA from the following five areas: southern Pennsylvania, Cecil County, Maryland's Eastern Shore, northern Montgomery County, and Frederick County. As the number of aggregate-producing operations within the area declines, either through depletion of deposits or land use restrictions, more expensive imported materials will be needed to meet the demand.

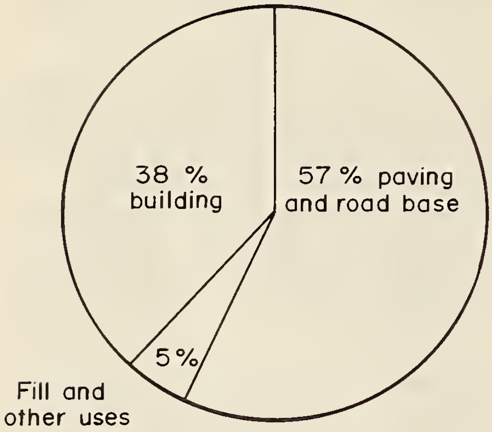
Concrete production consumes the greatest amount of aggregate material: sand as a fine aggregate, and crushed stone, gravel, or crushed blast furnace slag as the coarse aggregate. To obtain a usable concrete, the aggregates must possess sufficient structural strength and be chemically inert when mixed with the binding material (usually portland cement or asphalt). The concrete products that form the first uses of aggregates include contractor and ready-mixed concrete, concrete pipe, concrete block, precast and prestressed concrete units, and mortar. In turn, these products are utilized in highway and building construction.

As base material and fill, large amounts of coarse aggregates are consumed for road base and foundation construction. In highway construction, 60 percent of the aggregate consumed is utilized as base material, which provides a stable foundation for the bituminous or portland cement concrete pavement (5). Both coarse and fine aggregate material are utilized as fill around structures to improve drainage.

SAND AND GRAVEL



CRUSHED STONE



CRUSHED BLAST FURNACE SLAG

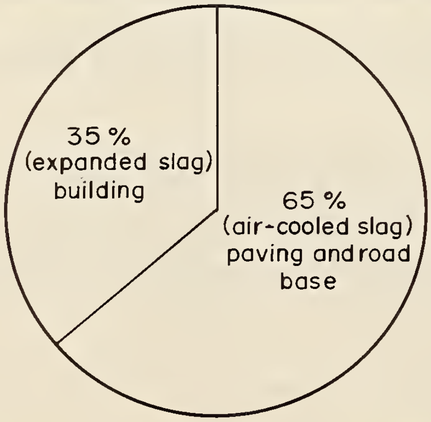


FIGURE 2. - Aggregate consumption by end use.

Federally financed highway construction in Maryland consumes an average of 48,000 tons of aggregates per million dollars of construction, which represents 13 percent of total construction costs (28). Aggregates account for approximately 28 percent of the cost of highway maintenance and repair (28). Aggregates and materials primarily composed of them represent 4 percent of the total cost of a single-family dwelling (23). Aggregates contribute approximately 2 percent of the total cost of nonresidential building construction, such as dams and bridges (20). For most of these construction activities (with the possible exception of asphalt pavement), not enough inexpensive substitute aggregate materials exist.

Consumption of the individual products--sand and gravel, crushed stone, and crushed blast furnace slag--is presented by end use in figure 2. Sand and gravel consumption is shown as a single chart because the data pertaining to the end use of these products are reported in a combined form. The category, "paving and road base," represents the amount of mineral aggregate material consumed by highway construction and includes other paving uses, such as parking lot and sidewalk construction. The building category represents all of the aggregates consumed in the construction of structures with the exception of fill, which is shown as a separate end use.

DEMAND FORECASTS

To determine the adequacy of the aggregate supply in the Baltimore SMSA, the future demand for these materials must be estimated. Table 1 shows the cumulative demand for sand and gravel and that for crushed stone from 1974 through 1980 and 1990. A projection model for blast furnace slag has not been developed because future production and consumption probably will remain about equal to the average annual production and consumption of the previous 10 years (4).

TABLE 1. - Cumulative demand for aggregates in the Baltimore SMSA, million tons

Commodity	1980	1990
Sand and gravel..................	33.2	84.3
Crushed stone....................	64.0	188.7
Crushed blast furnace slag.......	14.4	32.4

The demand projections attempt to provide a general estimate of the amounts of sand and gravel and crushed stone to be required by the Baltimore SMSA through the year 1990. Aggregate consumption in the Baltimore SMSA is based on Bureau of Mines production data and estimates of aggregate imports. Figure 3 shows the estimated consumption for sand and gravel and crushed stone, including production and imports for 1962-73. Figure 4 shows the projected demand for sand and gravel and crushed stone for 1974-90. Supporting data and the methodology utilized to obtain the demand projections are discussed in appendix A. Appendix B contains a list of aggregate producers in the Baltimore area during 1973.

The outlook for the area's economy through 1990 is one of continued growth based on projections of several regional economic indicators. The projections of economic activity as measured by the gross State product, the growth of the area's population, and the employment by contract construction in the area were obtained for the period through 1990 (appendix A).

The growth of construction activity in the Baltimore SMSA is projected by the index presented in table 2. This index was developed with information concerning contract construction earnings (in constant 1967 dollars) obtained from the OBERS[3] projections done for the U.S. Water Resources Council (27). Highway construction, particularly for freeways, probably will continue at the current pace until the mid-1980's (11). The demand for housing between 1974 and 1990 is expected to grow at a rate 33 percent greater than the growth during the previous decade (3). Extensive construction activity is anticipated for the Port of Baltimore, Baltimore-Washington International Airport, and for Baltimore's rapid mass-transit system from 1974 to 1990 (3).

TABLE 2. - Index of growth and projected growth of contract construction earnings in the Baltimore SMSA (1959 = 100)

Year	Index No.
1959..............................	100.00
1968..............................	136.29
1970..............................	160.55
1975..............................	181.92
1980..............................	218.01
1985..............................	262.88
1990..............................	316.93

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[3] OBERS is an acronym for a program involving reports done by the Bureau of Economic Analysis, formerly the Office of Business Economics (OBE) of the Department of Commerce, in conjunction with the Economic Research Service (ERS) of the Department of Agriculture.

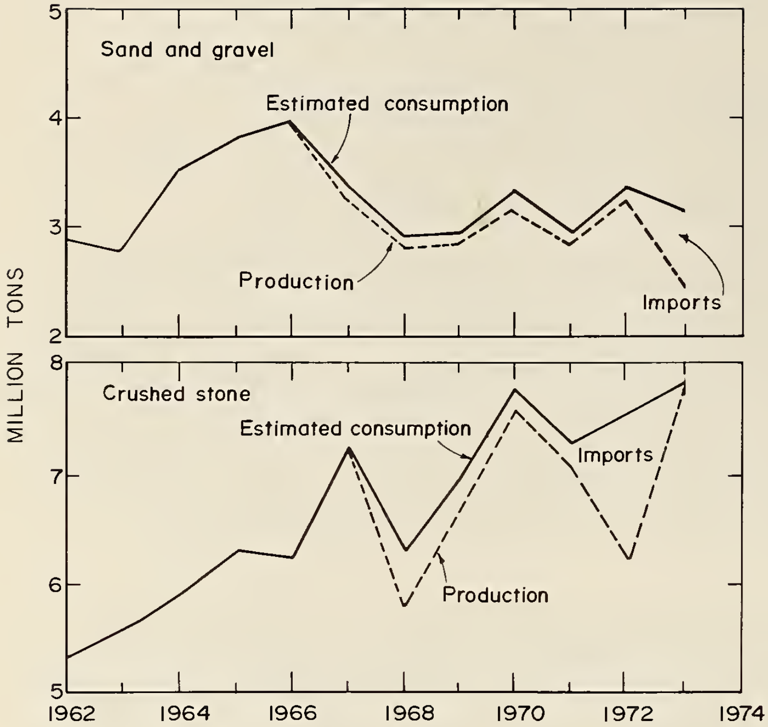

FIGURE 3. - Estimated consumption of sand and gravel and crushed stone, 1962-73.

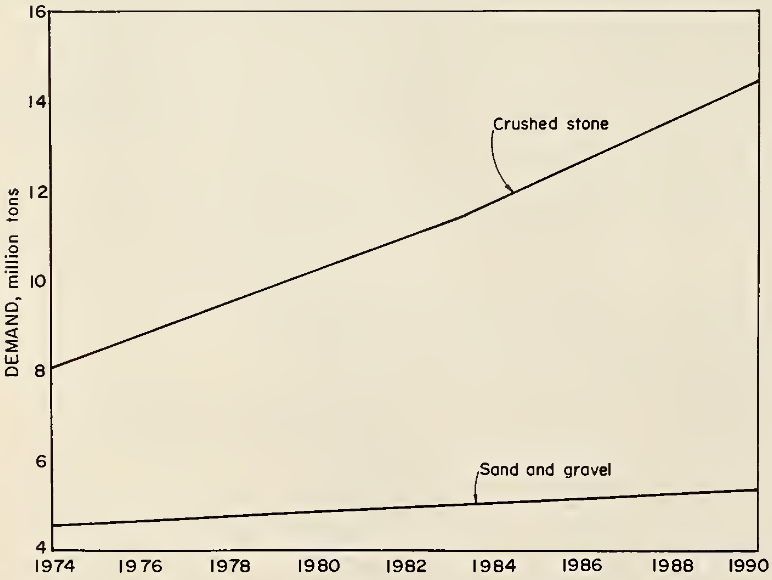

FIGURE 4. - Projected demand for sand and gravel and crushed stone, 1974-90.

GEOGRAPHY AND GEOLOGY

The Baltimore SMSA is contained within two physiographic provinces, the Coastal province and the Piedmont province, as shown by figure 5. The Coastal province is an area of relatively flat plains and low hills underlain by unconsolidated sedimentary rock from which all of the area's sand and gravel production originates. The Piedmont province is a region of higher elevation and more pronounced topography underlain by crystalline metamorphic rock. Most of the area's crushed stone production originates in the Piedmont province. A region of transition between the provinces, a few miles wide, is known as the Fall Line. The name of this region is reflected by the numerous waterfalls occurring as the rivers and streams of the region pass from the resistant Piedmont rock to the more easily eroded rock of the Coastal province.

Sand and gravel is present in several geologic formations in the Baltimore area: the Lowland deposits, which include the Wicomico and Sunderland formations; the Brandywine formation of the Upland deposits; and the Patapsco and Patuxent formations of the Potomac group. The Potomac group is the most important source of sand and gravel, which is being mined in Anne Arundel, Baltimore, and Harford

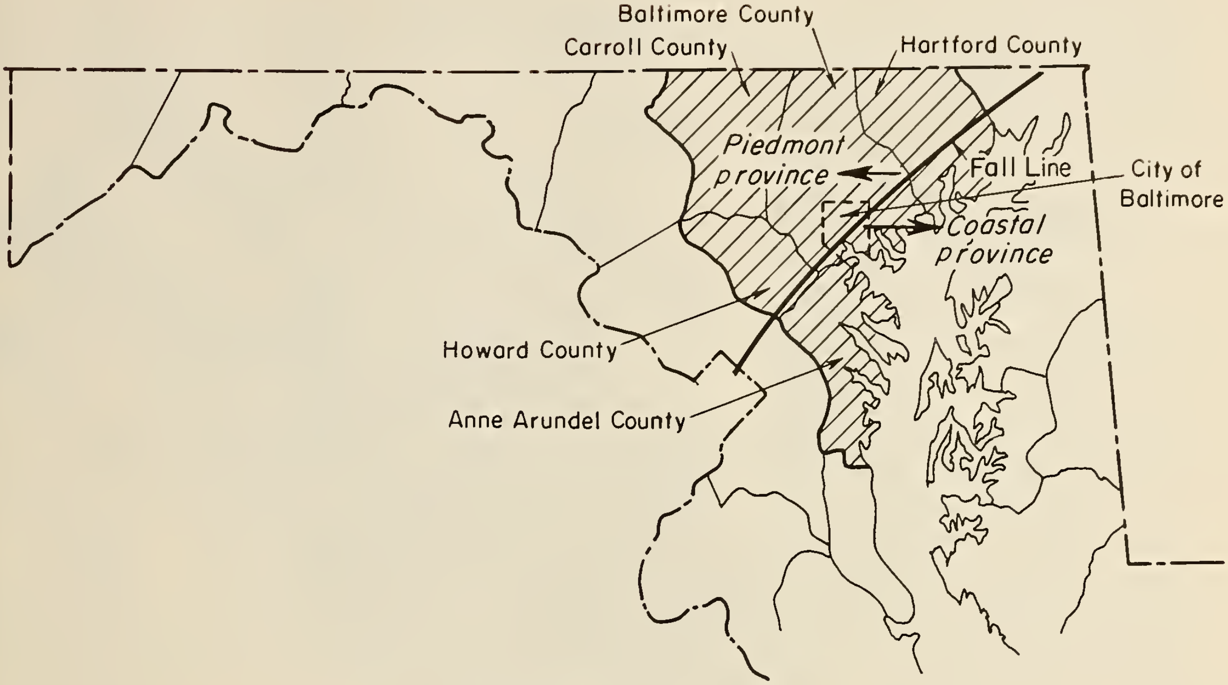

FIGURE 5. - Physiographic provinces.

Counties. The gravel of the Upland deposits has been mined in isolated areas of these three counties. The Lowland deposits are mined for sand and gravel in some areas of Anne Arundel County.

Rock found in the Baltimore area, which can be utilized as crushed stone, consists primarily of gabbro, gneiss, granite, marble, and serpentine. The most important source of crushed stone is Cockeysville Marble, which is being quarried in Baltimore and Howard Counties. Gabbro is quarried in Baltimore and Harford Counties, gneiss in Harford County, and some serpentine in Baltimore County.

Figure 6 gives the general location of the current and potential sources of natural aggregate material in the Baltimore SMSA. Although these sources of aggregates occur over relatively large areas, deposits suitable for mining occur on a widely scattered basis throughout these areas.

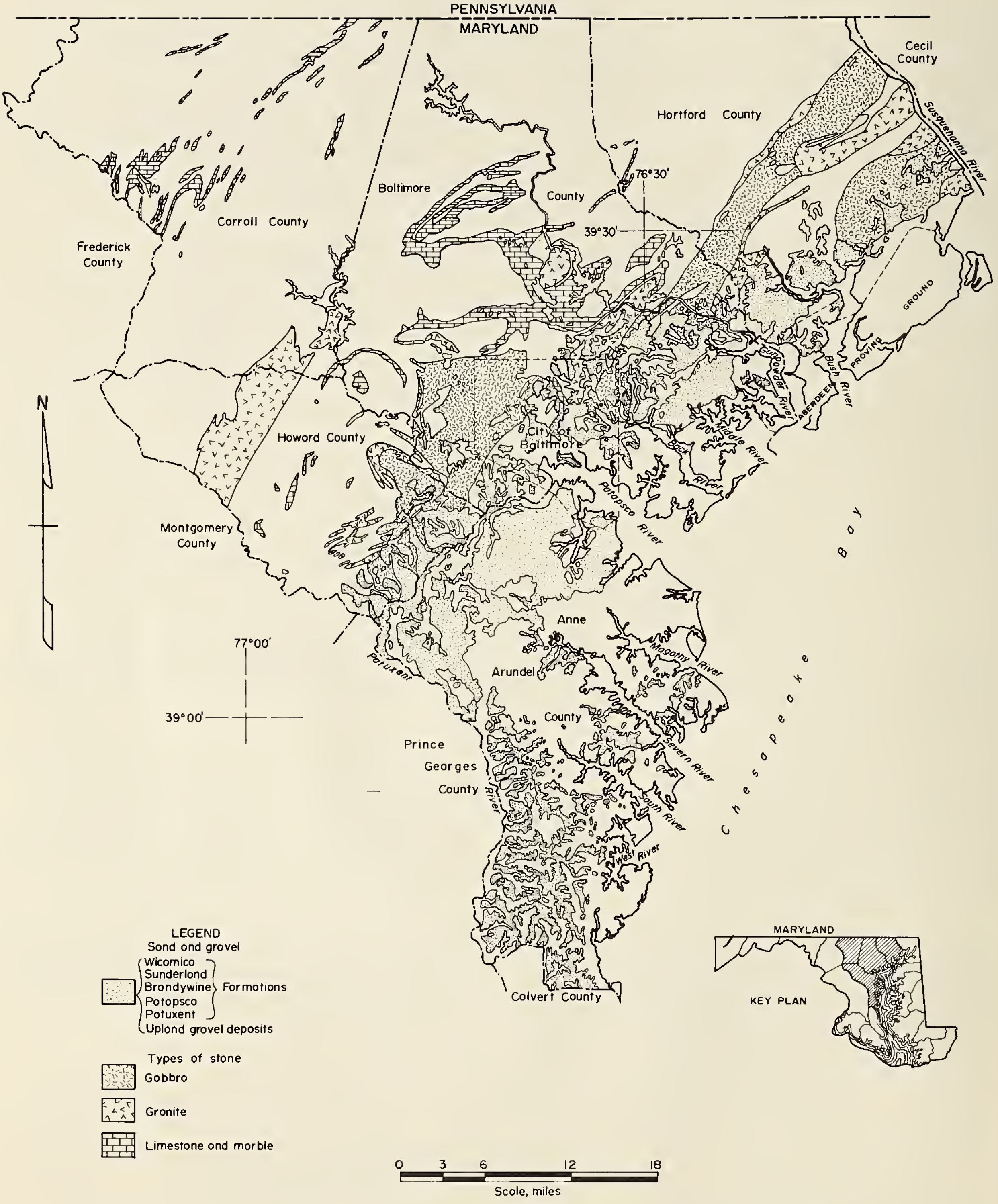

FIGURE 6. - Location of current and potential sources of natural aggregates.

MINERAL AGGREGATE SUPPLY

The aggregate supply for the Baltimore area is obtained from within the area and from southern Pennsylvania, Maryland's Eastern Shore, and northern Montgomery, Cecil, and Frederick Counties, Md. Figure 7 presents the general pattern of aggregate flow, which is from the outer fringes of the area toward the city. The flow of sand and gravel is concentrated along a corridor east of the Fall Line running north and south toward Baltimore City, whereas that of crushed stone is less concentrated, generally from the north and west toward the city. Along these flow lines both consuming and producing points exist, but most of the aggregates are shipped into the city and surrounding suburbs.

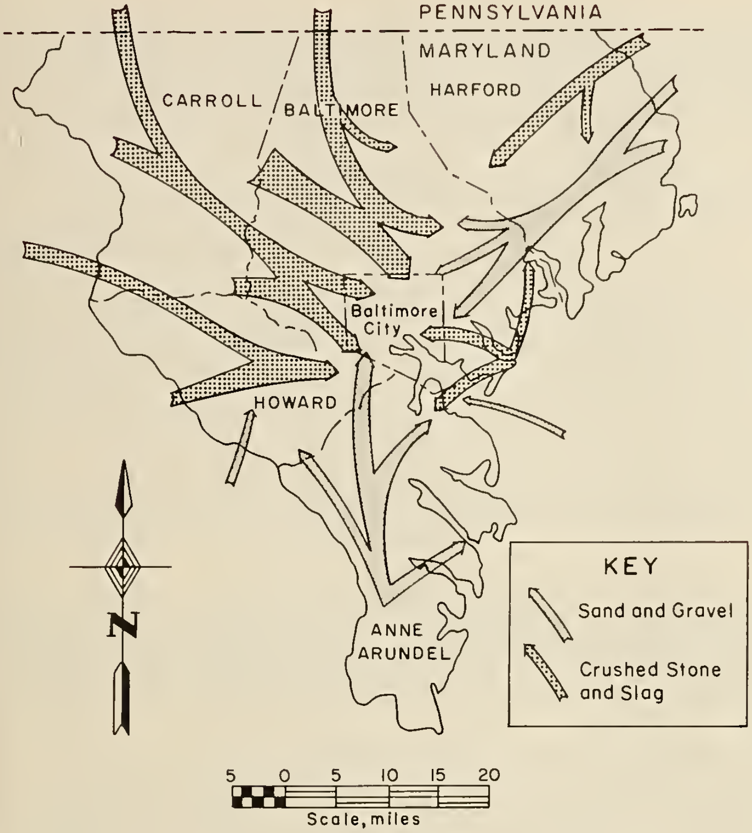

FIGURE 7. - Pattern of aggregate flow.

As of January 1974, the estimated reserves of aggregates in the Baltimore area were as follows, in million tons:

Sand and gravel............	139.0
Crushed stone..............	20,100.0
Crushed slag (annually).....	1.8

The estimated reserves of sand and gravel were determined on the basis of seven factors:

Area of resources (1971)[1]..................................	acres..	24,800
Average thickness of deposits[1].............................	feet..	17
Density[1]...................................	tons per acre-foot..	1,612
Resource distribution factor[2]..		0.5
Recovery factor[3]...		0.75
Previous production from resource area.................	million tons..	92
Loss of resource to urban development (1972-73), not reflected by resource area..	million tons..	2

---

[1] Maryland Geological Survey.

[2] Reflects the irregular occurrence of sand and gravel deposits (20).

[3] Accounts for production and processing losses (communication with industry representatives).

The estimate for sand and gravel also reflects the loss of 21 million tons in Howard County resulting from recent zoning decisions, which have nearly eliminated mining operations within the county. However, these decisions could be reversed.

The reserves of stone were estimated on the basis of six factors:

Area of resources (1971)[1]	acres	80,150
Average thickness of deposits[1]	feet	150
Density[1]	tons per acre-foot	3,594
Resource distribution and recovery factor[2]		0.5
Previous production from resource area	million tons	80
Loss of resource to urban development (1972-73), not reflected by resource area	million tons	144

[1] Maryland Geological Survey.

[2] Reflects the irregular occurrence of stone deposits and small production losses (20).

The estimate for stone also reflects the loss of 1,180 million tons due to the recent zoning decisions in Howard County; this loss reflects the depletion of current stone-producing operations over the 3 to 5 years following 1973. In the county, current stone operations can continue until depletion, but they cannot expand and new ones cannot be opened.

The availability of crushed blast furnace slag relates directly to the steel production at Sparrow's Point. Bethlehem Steel Corp. officials have indicated that future annual production of slag will approximate the average annual production between 1964 and 1973.

The supply of aggregates may be augmented for several areas that have not been considered in the estimates because of environmental, ownership, or information problems. The Aberdeen Proving Grounds and the Chesapeake Bay have potential supplies of sand and gravel that are not now available. In both areas, not only substantial geologic exploration, but also careful study of the environmental impact would be required before mining operations could be considered.

SUBSTITUTE AGGREGATE MATERIALS

Substitute aggregate materials are sometimes used in place of sand, gravel, crushed stone, or crushed blast furnace slag because of the special properties which these materials exhibit. Main applications are to satisfy the need for lightweight, superior insulation or acoustical properties.

Vermiculite, perlite, and pumice--materials of volcanic origin--are used mainly in concrete block and plaster for insulation and sound absorption. As lightweight aggregates, they compete directly with sand and expanded blast furnace slag. All of these materials must be transported into the Baltimore SMSA from the Western United States or from the Mediterranean region of Europe. In addition, vermiculite and perlite must be thermally processed before being used as aggregates.

Expanded slate, shale, and clay are utilized as aggregate material in concrete block and lightweight structural concrete, primarily in constructing tall buildings and long-span bridges. Some of these materials require not only mining and crushing before thermal processing, but crushing and sizing afterwards to produce an acceptable aggregate material. Currently, commercial operations producing expanded slate, shale, or clay do not exist in the area, although the slate of the Peach Bottom Formation in northern Harford County could be used for this purpose (19).

Fly ash, a waste product of coal burned in powerplants, requires pelletizing and thermal processing before it can be used as an aggregate, primarily in concrete. High processing costs have limited the use of fly ash in the Baltimore SMSA.

Another source of aggregate material is concrete from demolished buildings. After crushing and sizing, this concrete can provide low-cost aggregate when processed on the site by a portable unit.

Oyster shell from Chesapeake Bay could provide suitable aggregate material. However, the environmental problems created by dredging operations within the oyster beds and the economic importance of oysters generally preclude the availability of oyster shell as aggregate material.

These substitute materials cost significantly more to use than the conventional aggregates due to thermal processing and greater transportation distances. Rising fuel costs will widen this differential. Those materials, such as concrete from demolished buildings, which do not involve thermal processing or long-distance transportation are generally not of a large enough volume to significantly affect the market for mineral aggregates.

TRANSPORTATION

At least 50 percent of the delivered price usually consists of transportation costs (5). These high transportation costs divide the aggregate industry into regional markets; producers in one region are insulated from outside competitors by the prohibitive costs of shipping the product long distances. In certain situations, large producers taking advantage of the available economies of scale may be able to market aggregates competitively in adjoining regions. Some producers with access to navigable waters or railroads for unit-train shipments can compete with those in other regions. In the Baltimore area, production originating in other areas represented approximately 12 percent of the aggregates consumed in 1973.

The three transport modes available in the area are truck, rail, and barge. Deciding which mode is to be used usually depends upon the available transportation facilities and the size of shipments. Essentially, all final deliveries are made by truck even if the primary transportation is by rail or barge.

According to representatives of the aggregate industry, during 1973 trucks carried 95 percent of the aggregates shipped within or into the area.

Trucks are used for short hauls with one-way distances of generally less than 40 miles (20). The one-way truck haul in the Baltimore SMSA averages between 15 and 20 miles. However, with the "back haul" method, this range sometimes can be extended by 55 or 60 miles. When this method is used, the truck delivers a product and then is loaded with a second product for the return trip (20).

Two advantages of trucks are flexibility of shipment and lower fixed costs. Trucks can deliver aggregates to any consuming point in the Baltimore region. In contrast, trains are confined to those areas where track exists; barges, to navigable waterways. Fixed costs are lower for trucks because loading facilities are smaller and less sophisticated. The higher variable costs (those resulting from the use of the trucking equipment) involved are countered by the lower fixed costs and greater flexibility for one-way distances of less than approximately 50 miles. Trucks provide greater marketing flexibility, enabling smaller shipments to be made to smaller consumers over a more diverse area.

Trucks can be owned by the aggregate producers or leased on a contract basis from independent drivers and trucking companies. In the Baltimore SMSA, according to industry representatives, 25 percent of the trucking is owned by the producer and 75 percent is contracted. The average cost of truck transport is $0.25 for the first ton-mile and $0.07 for each additional ton-mile, which means that based on the total average mineral aggregate f.o.b. price of $3.11 per ton, the price doubles in the first 42 miles of transport.

Rail transport accounts for approximately 3 percent of the aggregates shipped within or into the Baltimore area. Rail transport can be utilized for distances of greater than 55 miles where navigable waterways or barging facilities are not available.

Using rail transport can involve some disadvantages, such as the shortage of hopper cars and the less-than-priority service that railroads provide to aggregate producers. Sometimes a rail car moved in a conventional train requires 5 to 7 days to move 15 to 20 miles, whereas a truck costing approximately the same amount can deliver the same tonnage in less than 8 hours by making 3 to 5 trips (15). Rail rates, usually quoted on a point-to-point basis, often involve track-switching and car-weighing fees. To obtain a comparable cost figure, approximately $0.75 must be added to the quoted rate for the cost of loading and unloading.

Unit trains carry only one product, use special equipment and loading procedures, and run only between the producer and consumer. Transport costs can be lowered 35 to 80 percent (15). To be successful, a unit-train operation requires large, uniformly distributed annual production and the modification of certain rail labor rules. The Chicago and Northwestern Railroad has such an operation for moving sand and gravel in the Chicago area (15). No unit-train service exists in the Baltimore SMSA.

Although barging is the cheapest way to transport aggregates 42 to 72 miles, it is the least flexible one. Using barges requires proximity to

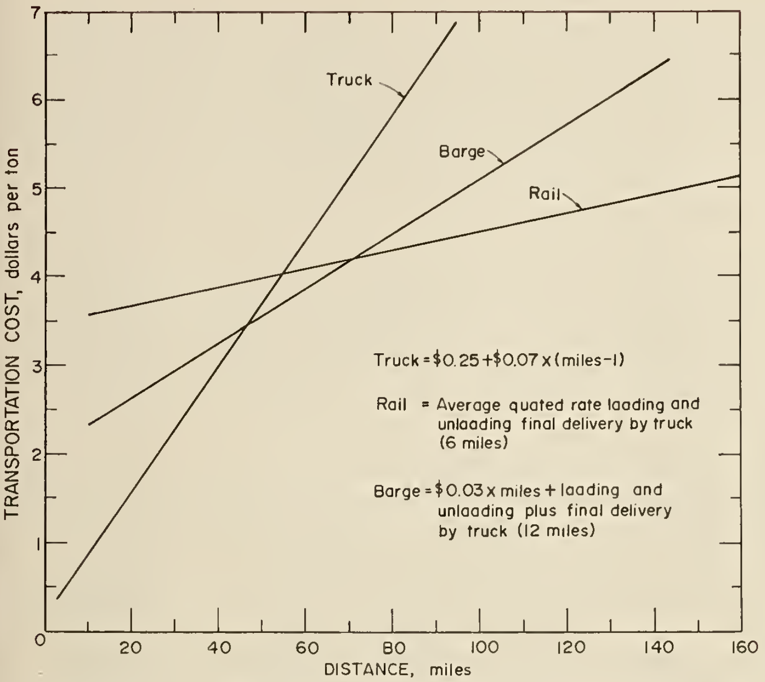

FIGURE 8. - Transportation cost per ton for truck, barge, and rail transport modes.

navigable waterways and availability of specialized loading and unloading facilities. About 2 percent of aggregates shipped within or into the Baltimore SMSA utilizes barge transport. Most of the barge traffic involves shipments between Baltimore and the Eastern Shore of Maryland. According to industry representatives, using barges costs about $0.03 per ton mile, plus $1 for loading and unloading.

Figure 8 is a comparison of the distance and the transportation cost per ton for the various transport modes. The barge costs include an additional $1.02 per ton to reflect an average truck haul of 12 miles from the barge unloading point to the consuming location. Similarly, rail costs include $0.60 per ton to reflect an average truck haul of 6 miles.

In the Baltimore SMSA, trucking will remain the primary mode of aggregate transport with some increase expected in the use of barge shipment as depletion and urbanization force producing plants to be located farther away from the central urban areas. Increases in the use of rail transport will be dependent to a certain extent upon the solutions that are obtained to many of the financial and operating problems troubling the area's railroads.

CONSTRAINTS ON AGGREGATE AVAILABILITY

The constraints governing the use of aggregates are geologic, economic, or political. The primary constraint is geologic. Minable deposits of aggregates occur in a limited number, with the locations of these deposits determined by ancient geologic processes. These deposits, containing a finite amount of aggregates, are limited because the geologic processes that produced the deposits required hundreds of thousands of years.

Economic constraints are the costs of mining and transporting the aggregates. The costs the producer can sustain are determined by the price he obtained for the aggregates. This price limits the quantity and quality of the aggregates produced and the distances they can be shipped. Over the short run, these constraints are essentially fixed, but over the long run, they are affected by changes in technology and in the demand for aggregates. Planning agencies attempting to optimize the use of available aggregates have little control over the economic constraints.

Political constraints are the only ones that can be significantly modified to obtain optimal use of aggregates. These constraints involve the development of urban areas in conjunction with the land use or zoning regulations that affect aggregate producers and the land on which aggregate deposits occur. The aggregate industry is affected by urban development in primarily two fashions. This development requires construction activity which provides the demand for the aggregates the industry wishes to sell. Forced by economic constraints to be located as near to the urban center as geologic constraints will permit, the expansion of the urban area often inundates the producing operation. For the period 1973 through 1990, 7.18 percent of the area's land is expected to be covered by additional urbanization (2-3). This would be approximately 1,600 acres and represents a loss of about 16 million tons of potential sand and gravel production.

Urban expansion and land use conflicts often restrict the aggregate producer's operation. These restrictions may relate to when operations may be conducted, methods of operation (such as crushing and blasting), or methods of transporting finished products. Such restrictions are often enforced by issuing short-term operating permits only when the restrictions are met by the producer; sometimes they are so severe that profitable operations would be impossible. In addition, permit renewals may be denied, thus prematurely terminating production. As a result the producing firm abandons the current site containing usable aggregates and starts searching for another minable deposit located farther away from the urban market area.

As the sand and gravel supply in the area diminishes, imported sand will become more important. However, this source will not be inexpensive for the consumer. When the areas surrounding the Baltimore SMSA become more urbanized, the producers outside the area will be as restricted as those within it; then these producers will be forced to move farther out and to pay higher transportation costs. In turn, the prices of the delivered product will rise. According to industry representatives, using an alternative to sand imports, stone sand (finely crushed rock), would increase the current f.o.b. prices 200 to 300 percent.

Although this area has a relatively abundant supply of crushed stone, using it will involve problems. Urban development has inundated several operations and is rapidly preempting virgin deposits. This preemption is not as critical as the loss of sand and gravel deposits, but it does present a planning problem. Usually the operation of stone quarries is more objectionable to local residents than operation of sand and gravel pits. Although sand and gravel pits disturb more surface area, rehabilitating abandoned quarries that have steep stone walls is more difficult. Quarry operations that produce a usable aggregate and also conform to zoning restrictions may not be possible. For example, in 1971, such restrictions closed the Savage Quarry in Howard County although the deposit was not depleted.

Higher aggregate prices caused by increased transportation and operating costs will affect the people in the Baltimore SMSA both as consumers of private construction and as taxpayers supporting public construction. The most significant impact will be on highway construction and maintenance programs, which require large amounts of both fine and coarse aggregates. Affected to a lesser extent will be large public projects, such as dams and bridges and nonresidential building construction. If the delivered price of aggregates were to double, which is quite possible, the area would be confronted with an increase of $41,691,000 in construction costs.[4]

CONCLUSIONS

A comparison of aggregate supplies and future demand in the Baltimore SMSA indicates some potential problems (table 3). Although future supplies of crushed slag are expected to be constant, and stone supplies ample, the available sand and gravel supply in the area is not expected to meet the anticipated demand beyond 35 years. This conclusion does not consider the following: (1) In addition to production, continuing urbanization makes sand and gravel unavailable and therefore each year reduces the supply by 1 million tons; (2) the future rate of consumption will probably increase; and (3) future zoning decisions may adversely affect supplies. Although imports may extend the life of existing supplies, depletion is already in sight, as well as the problems and higher costs associated with material shortages. The ultimate depletion of supplies may be inevitable, but it is in the public interest for planners and the mineral industry to conserve resources of sand and gravel so that maximum use may be attained from the available supply.

TABLE 3. - Supply and demand for aggregates, million tons

Commodity	Supply January 1974	Demand through--	
		1980	1990
Sand and gravel..........	139.0	33.2	84.3
Crushed stone...........	20,100.0	64.0	188.7
Crushed slag............	1.8	14.4	32.3

Possible solutions to the land use conflicts affecting aggregate supplies include the establishment of natural resource or mineral resource zones (12), the encouragement of sequential land use in conjunction with aggregate producing operations, and more consideration by producers to solve the environmental problems associated with aggregate production.

Before a mineral resource zone can be established, aggregate deposits must be located by analyzing geologic information. Within the zone, aggregate extraction would be given priority over other land uses for a specified time, usually 10 or 15 years. Also, in other areas of the zone, land containing deposits could be reserved for future supplies. Depleted areas within the zone could be reclaimed by requiring that they be restored for later use.

In sequential land use, the use of the depleted aggregate site is planned before mining operations commence. Thus, a deposit can then be mined and reclaimed in a manner that would best prepare the site for the subsequent land use.

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[4] Based on information obtained from 1972 Highway Statistics (29), 1973 Maryland Statistical Abstract (18), Fifth District Figures (1), and communications with the Maryland Highway Administration.

The avoidance of land use conflicts hinges to a considerable extent on the ability of the industry to maintain environmentally compatible operations. The inadequate reclamation of past production sites has resulted in the public image problems faced by the industry today.

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APPENDIX A.--DEMAND FORECAST METHODOLOGY AND SUPPORTING DATA

The demand projections for sand and gravel and crushed stone were obtained by using least-squares regression analysis. Table A-1 presents the data that form the basis for the statistical relationships utilized by the projection methods. These data consist of seven indicators of economic and construction activity used as the independent variables in both simple linear regression and multivariate linear regression analysis. The multiple regression models tested yielded unsatisfactory results mainly because of a high degree of correlation among the independent variables. Some of the variables utilized in simple linear regression analysis are listed in table A-2 with the associated coefficients of determination (r^2).

Projections of sand and gravel were obtained by using a simple linear regression model: Sand and gravel consumption for the Baltimore area in a specified year was related to the value of residential contract construction in Maryland during the previous year. The regression equation takes the form

$$Y = \underset{(317.87)}{2{,}795.16} + \underset{(0.57)}{2.69}\ X.$$

The projections of demand for crushed stone were obtained through the use of a simple linear regression model relating crushed stone consumption to the Maryland gross State product. The regression equation takes the form

$$Y = \underset{(698.67)}{2{,}503.31} + \underset{(46.7)}{279.61}\ X.$$

The numbers in parentheses under each regression coefficient are the respective standard errors of the coefficient estimates. Values for the t-statistics calculated from these standard errors indicate that the coefficients are significant at the 5-percent level. Table A-3 contains the values of the coefficient of determination (r^2), the F-test (F) and the Durbin-Watson statistic (d) for both the sand and gravel and crushed stone regression models. The coefficient of determination is a measurement of the variation of the dependent variable (Y), as explained by the variation in the independent variable (X). The F-test is a measure of the overall significance of the regression model. The values of F in table A-3 indicate that both regression models are significant at the 5-percent level. The Durbin-Watson statistic provides an indication of the autocorrelation problems affecting the regression. The values of d obtained for each regression model indicate that autocorrelation is not present. (Reference 17 presents a more detailed explanation of all the statistical tests.)

The t-statistics calculated from the standard errors of the regression coefficients indicate that the coefficients are significant at the 5-percent level. Table A-4 lists the projections of the independent variable utilized by the models; table A-6 lists the annual projections of sand and gravel and crushed stone demand for 1974-90.

TABLE A-1. - Basic data

Year	Baltimore SMSA population,[1] thousands	Average annual employment in contract construction, Baltimore SMSA,[2] thousands	Residential units, authorized, SMSA,[3] thousands	Maryland index of new housing starts, 1967=100[4]	Maryland nonresidential contract construction value,[4] million 1967 dollars	Maryland residential contract construction value,[4] million 1967 dollars	Maryland gross State product,[4] billion 1967 dollars	Crushed stone consumption, Baltimore region, thousand tons	Sand and gravel consumption, Baltimore region, thousand tons
1962	1,855	38.7	12.4	132.3	344.5	478.9	10.6	5,244	3,905
1963	1,893	38.6	16.3	173.4	445.1	564.2	11.2	5,622	3,797
1964	1,917	40.1	16.7	149.6	407.1	707.0	12.1	5,902	4,511
1965	1,944	41.4	16.0	190.4	468.2	750.7	13.1	6,323	4,808
1966	1,971	43.5	17.1	157.4	424.0	609.6	14.1	6,288	4,977
1967	1,997	42.3	14.8	100.0	409.5	445.8	14.6	7,284	4,344
1968	2,021	41.5	13.9	103.5	406.6	440.2	15.4	6,239	3,882
1969	2,051	42.0	14.7	102.5	477.2	451.7	16.1	6,944	3,897
1970	2,077	43.3	16.4	78.4	450.7	355.8	16.4	7,755	4,290
1971	2,150	46.9	21.1	143.3	360.8	543.3	16.8	7,249	3,891
1972	2,107	44.7	26.4	156.3	386.1	635.5	17.7	6,950	4,342
1973	2,118	46.2	23.0	171.3	428.5	657.7	18.9	7,791	4,116

[1] Maryland Department of Health.
[2] City of Baltimore, Planning Commission, Department of Planning.
[3] Baltimore Regional Planning Council, Housing Production 1973.
[4] Maryland Statistical Abstract, 1973.

TABLE A-2. - Coefficients of determination (r^2) between sand and gravel and crushed stone demand and selected economic indicators

Economic indicator	Coefficient of determination (r^2)	
	Sand and gravel	Crushed stone
Baltimore SMSA population	0.019	[1]N.S.
Baltimore SMSA number of residential housing units authorized	.010	0.250
Maryland gross State product	.004	.782
Maryland value of residential contract construction	.268	.048
Maryland value of residential contract construction (1-year lead)	.712	[1]N.S.
Maryland value of nonresidential contract construction	.061	.054
Maryland index of new housing starts	.099	[1]N.S.
Maryland index of new housing starts (1-year lead)	.554	[1]N.S.

[1] N.S.--not significant. The values for these indicators were not significant as a result of the standard statistical tests of significance (t-test, F-test) or as a result of an incorrect sign for the equation parameters.

TABLE A-3. - Coefficient of determinations, F-test and Durbin-Watson statistics

Commodity	r^2	F	d
Sand and gravel	0.712	22.17	1.55
Crushed stone	.782	35.81	2.68

TABLE A-4. - Projections of the basic data utilized in projection models

Year	Maryland gross State product,[1] billions 1967 dollars	Year	Maryland residential contract construction,[2] million 1967 dollars
1974	20.0	1973	657.7
1975	21.1	1974	686.6
1976	22.3	1975	716.9
1977	23.6	1976	728.3
1978	24.9	1977	740.0
1979	26.6	1978	751.7
1980	27.9	1979	763.8
1981	29.1	1980	776.0
1982	30.4	1981	793.8
1983	31.8	1982	812.1
1984	33.6	1983	830.8
1985	34.6	1984	849.9
1986	36.1	1985	869.4
1987	37.7	1986	889.4
1988	39.4	1987	909.9
1989	41.1	1988	930.8
1990	42.9	1989	952.2
		1990	974.1

[1] Based upon information provided by the Maryland Department of Economic and Community Development.

[2] Based upon information provided by the National Association for Home Builders.

TABLE A-5. - Projected SMSA population and employment in contract construction, thousands

Year	Baltimore SMSA population[1]	Baltimore SMSA employment in contract construction[2]
1974	2,127	47.6
1975	2,139	49.0
1976	2,151	49.8
1977	2,162	50.7
1978	2,238	51.6
1979	2,316	52.4
1980	2,398	53.0
1981	2,432	54.2
1982	2,467	55.0
1983	2,502	55.9
1984	2,538	56.8
1985	2,574	57.7
1986	2,611	58.6
1987	2,648	59.6
1988	2,686	60.5
1989	2,724	61.5
1990	2,761	62.5

[1] Maryland Department of Health.

[2] Based upon information provided by the City of Baltimore Planning Commission, the Employment Service of Baltimore Metropolitan Area, and Curtis Harris, Urban Economics, 1985.

TABLE A-6. - Annual demand projections for sand and gravel and crushed stone, 1974-90, million tons

Year	Sand and gravel	Crushed stone
1974	4.6	8.1
1975	4.6	8.4
1976	4.7	8.7
1977	4.8	9.1
1978	4.8	9.5
1979	4.8	9.9
1980	4.9	10.3
1981	4.9	10.6
1982	4.9	11.0
1983	5.0	11.4
1984	5.0	11.9
1985	5.1	12.2
1986	5.1	12.6
1987	5.2	13.0
1988	5.2	13.5
1989	5.3	14.0
1990	5.4	14.5

APPENDIX B.--AGGREGATE PRODUCERS

TABLE B-1. - Aggregate producers in the Baltimore SMSA, 1973

Company	Commodity	Producing locations	
		Town	County
Abend Brothers................	Sand and gravel	Davidsonville.	Anne Arundel.
Annapolis Sand and Gravel Co..	.....do........	.....do.......	Do.
Arundel Corp..................	Sand and gravel	.....do.......	Do.
	Stone..........	Delight.......	Baltimore.
	.....do........	Pikesville....	Do.
	Slag...........	Sparrows Point	Do.
Alan E. Barton, Inc...........	Sand and gravel	Odenton.......	Anne Arundel.
Belle Grove Corp..............	.....do........	Brooklyn......	Do.
Bethlehem Steel Corp..........	Slag...........	Sparrows Point	Baltimore.
Bob's Sand Co.................	Sand...........	Crownsville...	Anne Arundel.
Harry T. Campbell Son's Co., a division of the Flintkote Co.	Sand and gravel	White Marsh...	Baltimore.
	Stone..........	Randallstown..	Do.
	.....do........	Texas.........	Do.
Charles County Sand and Gravel Co., Inc.	Sand and gravel	Davidsonville.	Anne Arundel.
Charles F. Meyer & Sons.......	.....do........	Waysons Corner	Do.
Charles Jasper................	.....do........	Carney........	Baltimore.
Gatch Crushed Stone, Inc......	Stone..........	BelAir........	Harford.
W. Noble Hamilton & Son.......	Sand and gravel	Webster.......	Do.
Howard & Montgomery Crushed Stone Co.	Stone..........	Clarksville...	Howard.
I. W. Jenkins.................	Sand and gravel	Joppa.........	Harford.
Joppa Sand and Gravel Corp....	.....do........	Joppatowne....	Do.
Nottingham Properties, Inc....	.....do........	Carney........	Baltimore.
Reliable Asphalt, Inc.........	.....do........	Millersville..	Anne Arundel.
Harry A. Smuck & Sons.........	.....do........	Lansdowne.....	Baltimore.
N. G. Spencer & Son...........	.....do........	Abingdon......	Harford.
William Spiegel...............	Sand...........	Middle River..	Baltimore.
Stancills, Inc................	Sand and gravel	Aberdeen......	Harford.
	.....do........	Havre de Grace	Do.
	.....do........	Joppa.........	Do.
D. M. Stolzfus & Sons, Inc....	Stone..........	Churchville...	Do.

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